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A New Methodology for Assessing the Military Value of Tactical Intelligence and Surveillance Systems

by

Joseph Sternberg, Ross Thackeray and Frederick Johnson

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The objective of this program is to develop and apply a methodology for assessing the impact of indications and warning (I&W) information, derived from external sources, on the mission success of a naval carrier battle group CVBG). This would provide the basis for assessing the operational importance of the performance characteristics (timeliness, frequency of coverage, quality of information, etc.) of current or proposed information systems and to evaluate the consequences of enemy interference or deception. The need to account for operational decisions based on conflicting and incomplete information has led to the development of a unique wargame as a key element of the methodology.

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A New Methodology for Assessing the Military Value of Tactical Surveillance and Intelligence Systems

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Abstract

The objective of this program is to develop and apply a methodology for assessing the military value of indications and early warning (I&W) information, derived from external sources, on the mission effectiveness of a naval carrier battle group (CVBG). This would provide the basis for assessing the operational importance of the performance characteristics (timeliness, frequency of coverage, quality of information, etc.) of current or proposed information systems and to evaluate the consequences of enemy countermeasures on those systems. The need to account for operational decisions based on conflicting and incomplete information has led to the development of a unique wargame as a key element of the methodology.

Introduction

The value of indications and warning (I&W) information depends on how well it can be exploited. This in turn depends on two factors: first, the commander's interpretation and assessment of the information bearing on the employment decisions affecting his available forces. Second, the tactical outcome which is then determined by the relative engagement capabilities of the two sides. In seeking to improve the military outcome, there is clearly a tradeoff between enhancing the information available and improving the combat capability of the forces Hence a methodology for assessing the military value of surveillance and intelligence information must include simulations of combat capability to show how the outcomes of tactical engagements depend on the commander's tactical decisions in the use of his forces.

I&W information flows to the fleet via a number of channels. However, one external I&W source is clearly set apart by having a significantly shorter average elapsed time between the collection of the basic data by a sensor and the receipt of the information by units at sea. This channel is known as the TRAP broadcast. Because of its time

advantage, it is appropriate in developing the methodology to consider that all of the I&W flows in that channel.

The TRAP information reaching the commander may be conflicting, incomplete, and confused by enemy interference and deception. The importance of accounting for the impact of these characteristics of the information on the commander's tactical decisions leads to a man-in-the-loop methodology, i.e. a specially designed wargame. When played by experienced commanders, the wargame makes explicit the dynamic interaction between required decisions and the availablity and interpretation of information. Insights on the commanders' use and interpretation of information under the time pressures of a tactical situation are enhanced by recording player discussions during the game. Detailed variability in the game results is to be expected due to the inevitable variability in decisions by different players. But this variability is also a fact of combat. The objective, then, is to determine what aspects of the information flow to the players produce major changes in the military outcome and can be expected to be effective in spite of the variability in player decisions.

We have chosen to apply these general considerations by examining the impact of external source (nonorganic) information on the mission success of a naval carrier battle group (CVBG). The game scenario is an adaptation of a Middle-east contingency scenario developed by the Navy.(Ref 1) A multi-national naval force (without a carrier) is in the Persian Gulf. A complex war breaks out in the region committing all litoral nation friendly air forces to national taskings. Iran tries to hold the multi-national force hostage by threatening to bar passage of the Straits of Hormuz. A U.S. CVBG is ordered to the Gulf of Oman to support the breakout of the hostage force by destroying Iranian SSM weapon sites around the Straits of Hormuz (while minimizing losses of aircraft and damage to the battle group). In carrying out the assigned offensive mission, the CVBG will be threatened and subject to attack by Iranian missile-carrying tactical aircraft. The geographical setting and a few hypothetical, but representative, SSM sites and airfields are shown in Fig. 1. This is the basic geographical display available to the players. It is this display which is used to portray the players' understanding of the disposition of enemy assets. The locations of the SSM sites are shown by icons in the shape of small missiles, while the airfields are shown by crossed runways.

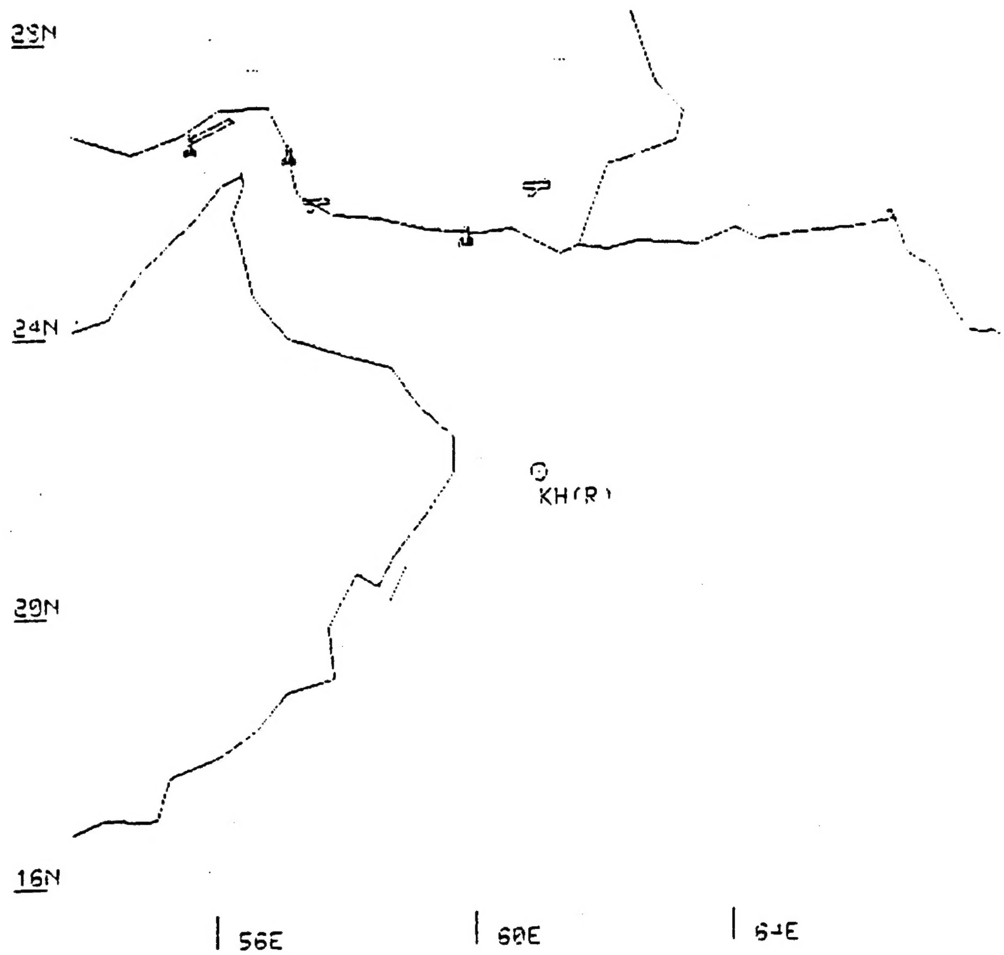

Fig.1. Geographic setting of scenario

The basis for assessing the offensive and defensive success of the battle group will be timeliness in destroying the SSM sites, limitation of damage to surface components of the battle group by enemy air-to-surface missiles (ASMs) and the losses of friendly aircraft as compared with enemy aircraft. These results will be evaluated in real time by the combat engagement models (representing expected levels of engagement capabilities) integrated in the game and will depend directly on the tactical decisions made by the commanders. These models must portray the engagement capabilities of both sides in much the same terms used in the study of hardware requirements, and the results of each engagement must be incorporated into the game in real time so losses on both sides will have their appropriate consequences in subsequent engagements. The central issue is to assess the contribution of the nonorganic information received via the TRAP broadcast to the offensive and defensive effectiveness of the battle group.

The information flowing to the players includes electronic intercepts from mission targets and enemy air defense elements, indications of potentially threatening enemy aircraft movements, IR intercepts and imagery results. The operational decisions on the use of carrier aircraft will be more or less effective depending on the quality, frequency, and timeliness of the information, and the interpretation and integration of the information by the players. The game also provides a framework for assessing the impact of proposed additions to the I&W information from new systems.

The players in the game represent the CVBG commander and the senior staff. The information flow is treated as a controlled variable so that it can be varied between games to represent changes in sensor capability or the consequences of enemy actions. While the goal is to have a methodology that is useful for assessing the value of information systems, the same methodology can be used to compare the gain in military effectiveness provided by new information systems to the gain in effectiveness provided by an improvement in combat capability due to the introduction of new weapon systems and tactics.

The Information Flow

In any study evaluating the military utility of capabilities or equipments, the scenario is a crucial feature. The scenario developed for this game has been described in general terms in the Introduction. Following are the specific aspects of the scenario that are converted to information in the wargame:

a) The characterization of the fixed and mobile elements of the enemy force, such as their geographical location, and on-off operational cycles, provides the data needed to determine the exposure to intercept of emissions by overhead systems. Figure 2 is a representative page from the scenario. It shows movements by units that comprise both complete targets and only portions of the assets originally comprising a target. The movements can begin and end both before and after the commencement of play; the times are specified to the nearest half-day; and the precise times are generated within the simulations. Of course, if a contact is received from a mobile system at its new location, the players will not be provided information about where the system relocated from or if it had simply been shut down previously. The intelligence picture will continue to show the mobile system at its old location, unless the players decide that something has changed and take it off the display.

b) A detailed specification of enemy air movements as part of the scenario serves as the basis for the generation of air movement TRAP messages as well as defining the ground truth aircraft tracks for the computer. Figure 3 lists three examples of typical enemy air movements in preparation for and during the conduct of an attack on the CVBG. The reconnaissance track is given as a series of way-points and times. It could also be given in the form of way-points and average flight speeds. The forward deployment shows the movement of aircraft from home to staging base in preparation for an attack on the CVBG. The attack is shown as the movement of raiding aircraft from a staging base to a "push point". From the "push point", the computer generates a radial course to the CVBG, wherever the players position it within the scenario-constrained operating area. Data from the Gulf war are used to determine the degree to which these movements might be reported by TRAP messages.(Ref. 2)

The players begin the game with initial intelligence on enemy resources: the location of enemy SAM and SSM sites, airfields, numbers and locations of enemy aircraft, command centers, etc. As the game develops, the bulk of the information on enemy movements and activities will be information gathered by systems nonorganic to the battle group and promptly transmitted to the battle group by the TRAP broadcast. However, the players can, if they wish, send out reconnaissance missions to gain intelligence on enemy threat systems, but this takes time and must be weighed against the urgency of accomplishing the assigned offensive missions. Some corrections to the intelligence picture

B.E. #	OLD SITE GEO NAME	TARGET	OFF	NU-B.E #	NU SITE GEO NAME	TARGET	ON
P185	GOMERAN ISLAND 26-42-46N/55-33-56E	EX-U. S. NIKE HERC SAM & AAA GUN SITE	10/PM	P212	BAMPUR (IRANSHAHR) 27-19-10N 60-30-30E	THIRD OF EX-U. S. NIKE HERC SAM & AAA GUN SITE	11/PM
P191	HAMADAN MILITARY AFLD (NEW) 35-35-24N/48-30-53E	COMBINED MOBILE SAM BATTERY & AAA GUN FIRE COORD CENTER	11/AM	P213	AL LIMAN 25-45-30N 56-15-40E	COMBINED MOBILE SAM BATTERY & AAA GUN FIRE COORD CENTER	13/PM
P191	HAMADAN MILITARY AFLD (NEW) 35-35-24N/48-30-53E	LONG RANGE SEARCH RADAR & C2	10/PM	P224	SHARAK 26-01-30N 61-04-05E	LONG RANGE SEARCH RADAR & C2	11/AM
P192	HAMADAN MILITARY AFLD (NEW) 35-16-41N/48-39-53E	SAM BATTERY & AAA GUN SITE. SAM TYPE UNKN'N POSSIBLY EX-SOVIET	11/AM	P226	HILL 1483 25-55-50N 58-55-00E	SAM BAT- TERY & AAA GUN SITE. SAM TYPE UKN POSS EX-SOVIET	13/AM
P205	JASK 25-38-21N/57-47-30E	THIRD OF COMBINED SSM BATTERY CONTROL CTR & LAUNCHER SITE	11/PM	P227	TUNB ISLAND 26-15-02N 55-18-15E	THIRD OF COMBINED SSM BAT- TERY CON- TROL CTR & LAUNCHER SITE	12/PM
P205	JASK 25-38-21N/57-47-30E	THIRD OF COMBINED SSM BATTERY CONTROL CTR & LAUNCHER SITE	12/AM	P232	TIDAT 26-05-52N 56-08-10E	THIRD OF COMBINED SSM BAT- TERY CON- TROL CTR & LAUNCHER SITE	13/AM
P205	JASK 25-38-21N/57-47-30E	THIRD OF COMBINED SSM BATTERY CONTROL CTR & LAUNCHER SITE	12/PM	P233	BURKHA 26-08-30N 56-08-50E	THIRD OF COMBINED SSM BAT- TERY CON- TROL CTR & LAUNCHER SITE	13/PM
P206	JASK 25-38-37N/57-49-18E	SSM LAUNCHER SITE	10/AM	P235	JAZIREH-YE- LARAK ISLAND 26-49-30N 56-20-05E	SSM LAUNCHER SITE	12/AM
P207	JASK 25-43-07N/57-48-21E	EX-U. S. HAWK SAM BATTERY & AAA GUN FIRE CORD'N CENTER	10/AM	P238	HILL 2103 25-50-30N 59-17-10E	EX-U. S. HAWK SAM BATTERY & AAA GUN FIRE COORD CTR	12/AM
P207	JASK 25-43-07N/57-48-21E	LONG RANGE SEARCH RADAR & C2	10/PM	P239	BARENSK (HILL 3622) 26-10-35N 58-48-20E	LONG RANGE SEARCH RADAR & C2	12/PM

Fig.2. Sample event list from scenario

a. A Reconnaissance Mission

Two F14, Esfahan based Tomcats, TNs F14321 and F14322, CS Chah Six, Northern Arabian Sea CVBG Recce.

Dep. Chah Bahr	25-27N/60-23E	111400Z
	23-00N.60-00E	111423
	21-00N/60-00E	111441
	21-00N/63-00E	111506
	24-00N/64-00E	111534
	25-00N/65-35E	111550
	25-27N/60-23E	111633 and Terminate

b. A Forward Deployment

Three MIG27, Omidiyeh based Floggers (two ASM and one escort jammer), TNs M27201, M27202 and M27212, moving from Omidiyeh to Chah Bahr.

Dep.	30-50N/49-33E	120400Z
	25-27N/60-23E	120539 and remain UFN

c. An Attack on the CVBG

Iranshahr composite Attack Mission consisting of Five MIG29 (Shiraz based Fulcrums, TNs M29055/56/58/59/61 and Escort Jammer M29065), and Four MIG27 (Omidiyeh based ASM-configured Floggers, TNs M27214-17 and Escort Jammer M27218). CS is Iranshahr 23. Altitudes are: for MIG 29, 25 kft; for Jammers, 15 kft; and MIG 27, <1000 ft.

Dep.Iranshahr,27-11N/60-42E	120900Z
25-00N/61-00E	120920, This is "push point" for attack on the CVBG.

Legend: TN = tail numbers, CS = call sign

Fig.3. Typical air-movement scenario events

may be contained in pilot reports from offensive actions, but the TRAP broadcast will remain the predominant source of vital information on enemy developments.

TRAP messages representing expected overhead contacts are generated by a simulator developed by the Navy's Operational Support Office. Information from service and theater systems may also be part of the message stream where the availability of such systems is consistent with the scenario. All of these messages will concern matters of vital interest to the players in deciding on offensive and defensive actions

The game is designed to show the military consequences of player decisions based on their perceptions of enemy activities, rather than on the scenario's "ground truth". The players cannot necessarily assume that the information they receive by TRAP is valid. It is recognized that in various ways the information collected is subject to interference or deception by the enemy. Thus an information flow for a game can be developed that incorporates such enemy actions and the impact of this "interference" on the evolution of the players' perceived intelligence picture and the military consequences can be evaluated. The fusion of nonorganic and organic information is not an automatic process since it depends on the players' assessment of the credibility of the TRAP messages. This methodology then provides a way to assess how much interference and deception by the enemy causes the TRAP messages to be ignored or downgraded in importance, which could then be the basis for system modifications designed to limit the consequences of possible enemy interference and deception.

The format of the TRAP messages for overhead contacts is shown in Figure 4. The message indicates the time of contact, the geographical location, the location-error ellipse, and the type of system detected. The top line in the message is for bookkeeping by the game computer and is not part of the message received by the players. Each enemy emitting system that is part of the scenario is given a P number and its correct location is specified. The message received by the players can only be identified by them by a message number which is chronologically determined. The emitter location given in the message will differ from the true location to reflect the lack of precision in locating emitters by electronic contacts.

The players use the geographical display for their area of operations to show their perception of the supposed location of potential enemy targets, defense systems and

TRAP MSG 0806 - 12MAR93 P137 27-12N 54-19E
EXER/EXERCISE MESSAGE//
MSGID/TACELINT/120806Z//
SOI/ - /120740Z/ - /ALT COMMAND CENTER//
EMLOC/ - /E//LS:271255N541929E/ - /126.9T/29.0NM/5.3NM//
NARR/MOBILE SURFACE SEARCH, ACQUISITION & TRACKING RADAR
DECL/OADR//
END_TRAP_MSG

TRAP MSG 2334 - 12MAR93 P204 25-43N 57-47E
EXER/EXERCISE MESSAGE
MSGID/TACELINT/122334Z
SOI/ - /122257Z/ - /MILITARY COMMAND CENTER//
EMLOC/ - /E/ LS:254317N57473E/ - /200.1T/31.8NM/20.4NM//
NARR/METEOROLOGICAL SOUNDINGS//
DECL/OADR//
END_TRAP_MSG

TRAP MSG 0842 - 12MAR93 P205 25-38N 57-47E
EXER/EXERCISE MESSAGE
MSGID/TACELINT/120842Z//
SOI/ - /120817Z/ - /COMBINED SSM BATTERY & CONTROL CENTER//
EMLOC/ - /E/LS:253821N574730E/ - /329.2T/47.6NM/17.1NM//
NARR/PRECISION SURFACE SEARCH RADAR//
DECL/OADR//
END_TRAP_MSG

Fig. 4 Sample TRAP Messages for Overhead Contacts

activity as well as the location of the battle group and its airborne defense elements (CAP aircraft, E2Cs). When a TRAP message is received, a flashing symbol identifying the emitting system appears on the display at the location given in the message. If the icon is "pucked", the TRAP message will appear on the screen. Fig. 5 shows such a message resulting from an intercept of an emitter at a surface-to-air-missile (SAM) site. The location is given by an icon, a capped-missile symbol, and the message is clearly linked to it. The players can decide to "accept" the data , which stops the flashing and leaves the system symbol on the display. If they wish to disregard the new data, the symbol can be removed from the display. If the symbol is retained, the TRAP message will be kept in a file and can be recovered at any time by the players for further consideration. Figure 6 shows a representative TRAP message for air activity. The locating icon is a Naval Tactical Data System (NTDS) aircraft symbol capped by the abbreviation"INTEL". The message is similar to the other classes of TRAP messages with the addition of fields for altitude, course and speed (when available) and an indication of whether the report is one of a series on the same aircraft, which could lead to the establishment of a track.

At the start of the game, the display shows the deployment of enemy radars, missile systems, etc, as specified by prior intelligence. It is assumed that this intelligence picture has been developed over a period of time from many intelligence sources so that it provides accurate location of enemy systems. As the game proceeds the supposed disposition of enemy forces is altered by the incoming TRAP messages, provided the players consider them credible. (At the same time, "ground truth" as determined by the evolutions detailed in the scenario is displayed for observers at a separate monitor station.) The greater the difference between "ground truth" and the players' perception of ground truth, the less effective the carrier force will be in carrying out its offensive missions and in defending itself.

General Game Design

The objective of the wargame design has been to generate a "realistic" decision environment for the experiments. The choice of the scenario avoids the introduction of factors that would blur the direct linkage of information-available to tactical decisions-made. In the early days of the depicted crisis, the CVBG commander is the joint task force commander. This gives the players a freer hand in offensive decisions. At some cost in realism and , after being assigned the overall offensive objective,.the players are granted on-scene commander's discretion by the NCA permitting them to order strikes on targets

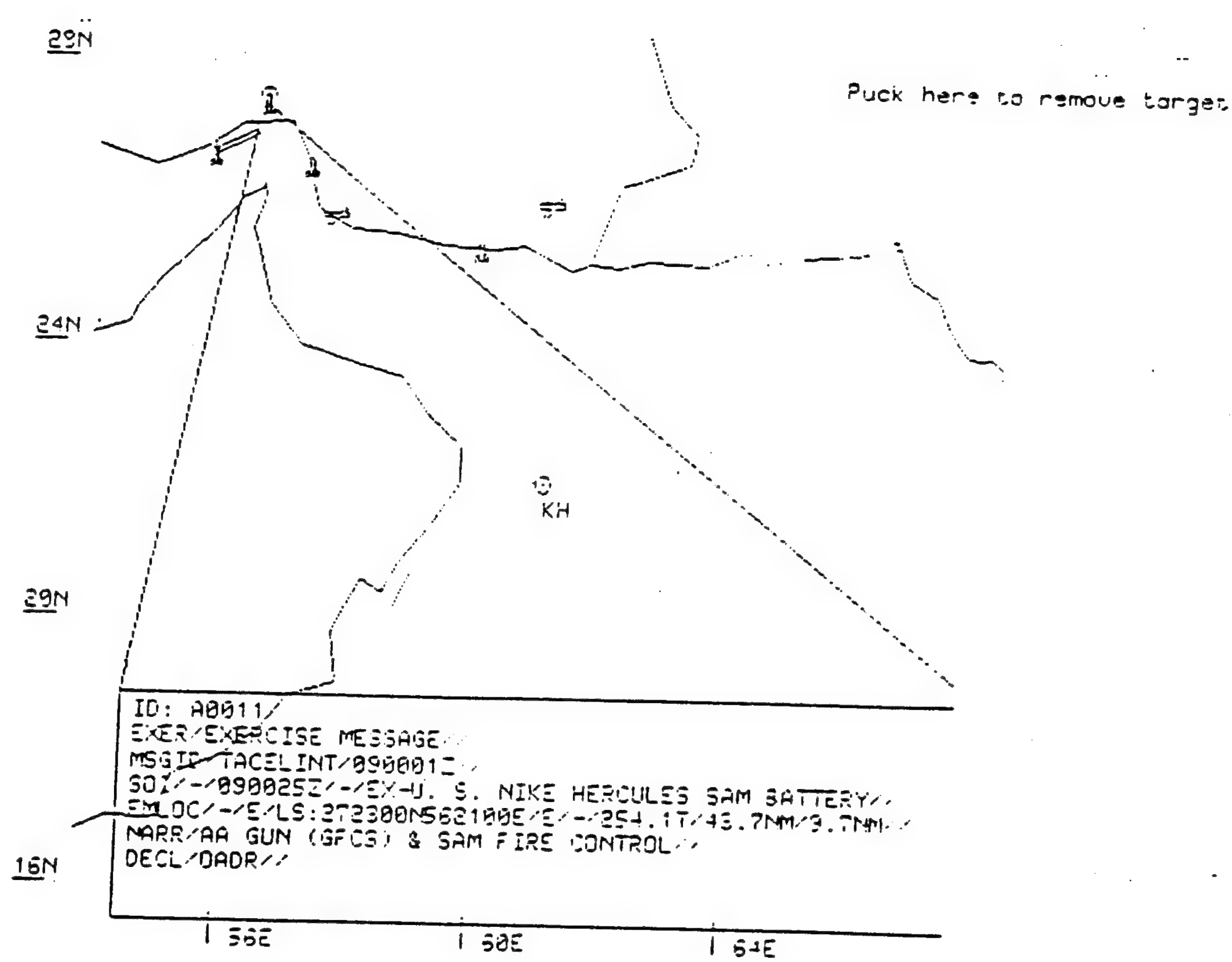

Fig.5. TRAP message for overhead contact of surface threat

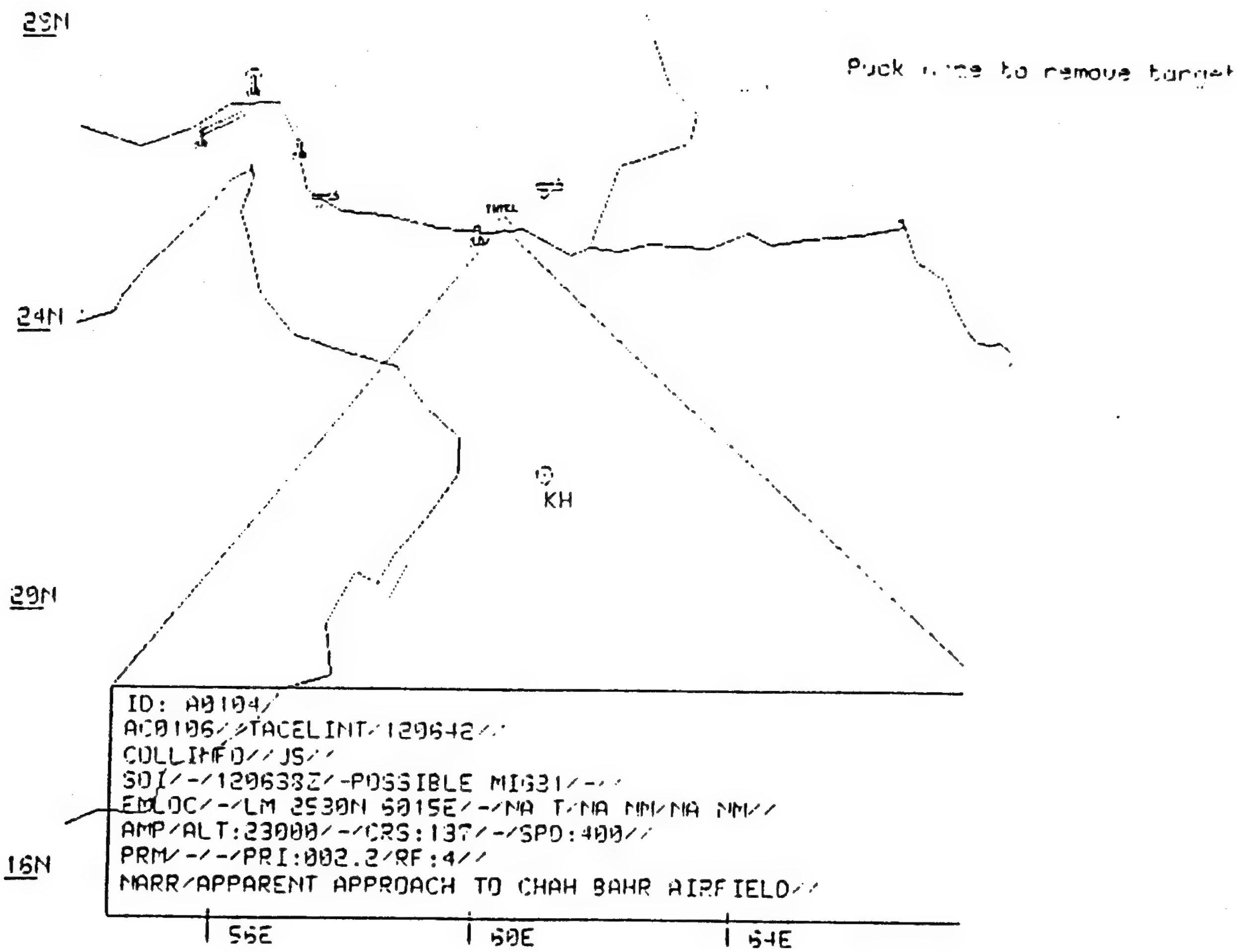

Fig.6. TRAP message for enemy air activity

their own selection, without referring these selections to theater or national authorities for approval. All of the action in the game is related to the employment of air assets and missiles by the two sides. The possible use of submarines by the "enemy" or amphibious landings by friendly forces is ruled out by the scenario.

The game is basically a one sided action, in that the location and movement of enemy assets as well as the detailed structure and timing of enemy air attacks on the CVBG are pre-scripted. However, the players' actions can modify the pre-scripted movement of enemy forces in two ways that are important to the objectives of these experiments. First, ground truth is altered on the basis of the results obtained in CVBG offensive strikes. The CVBG commander will credit strike results from air crew reports on the premise that aim points attacked are aim points destroyed; this is an assumption that can differ significantly from the true results. Second, if a target has been destroyed according to ground truth, then no additional TRAP messages of contacts from that particular target will be received by the players. Finally, the players may decide to execute strikes on enemy airfields for the purpose of reducing the enemy air threat to the CVBG. They have to balance such actions against early execution of the offensive tasks they have been assigned. Whether such actions appear, on balance, desirable will depend on the players' intelligence picture. If aimpoints are destroyed at enemy airfields, the weight of the pre-scripted enemy air attacks on the CVBG will be reduced in proportion to reflect a reduced operational capability at the enemy airfields. Thus these changes in the pre-scripted forces and actions of the enemy are brought about by the actions of the players in carrying out their mission. Otherwise, it is essential to keep the threat to the battle group constant from one play of the game to the next while the externally supplied information to the players is varied.

Given the choice of gaming as the basic technique, the next step was to settle on the functions and activities to be portrayed in the game and the level of detail with which each one should be simulated. A major concern was the level of detail to be used for the simulation of defensive engagements. The structure and timing of enemy attacks on the fleet are pre-scripted in the scenario. The players make decisions on the disposition of their defensive forces as the game proceeds and decisions on initial defensive responses as a feint or attack develops. These tactical decisions are directly influenced by their interpretation of the I&W information that has been received. Once these decisions have been made and forces committed in execution, the engagement simulation takes over and estimates their success in countering the attacking aircraft and the enemy's success in

launching missiles against and damaging elements of the battle group. In this way, the military value of the I&W information is assessed in real time in the game. The assignment of unit capabilities in the types of engagements that are encompassed in the simulation are based on the Navy's estimates of those capabilities. The interplay of information and weapon system capabilities is evident. Defensive engagements will be discussed in more detail later.

The simulation of the military consequence of offensive decisions was more straightforward. I&W information directly affects offensive decisions in two ways. The mission of the CVBG is to provide air cover and strike support for the escorted merchant ship convoy while that group exits the Gulf; suppression of surface-to-surface missiles threatening that movement is integral to the basic mission. The SSM sites are mobile and transportable introducing an increasing threat to the exiting convoy as new sites are activated. I&W information is crucial in establishing the presence and location of these sites about the Straits of Hormuz. Secondly, knowledge of enemy defensive elements, such as warning radars, SAM sites and interceptor aircraft, has a direct influence on offensive planning for the composition and size of the needed strike force. Availability of aircraft is a major constraint in this scenario. The greater the disparity between "ground truth" and the players' intelligence picture, the less effective the battle group will be in carrying out its offensive mission. As will be described later, elements of the Pacific Fleet Headquarter's THOR model have been adapted to the development of a Strike Operations Model which is used during offensive planning and and to simulate strike results against ground truth.

The game also provides for the receipt of scenario background information by the players in the form of various types of messages. These messages largely concern friendly and enemy activity in the Gulf beyond the immediate field of CVBG activity. Some of this information, such as the progress of the naval force out of the Gulf, is of direct importance to the timing of the players' decisions. The message flows are also an important contribution to the "reality" of the wargame, but must be limited to avoid overloading the players who in the real world would be supported by large staffs. Messages are therefore filtered and summarized in the form that reaches the players, because the intent is to show the impact of the information on decisions not to test the powers of the players to resist saturation.

Finally, for the intitial application of this methodology, the game will cover the last four hours of daylight on one day of combat and eight hours of the next, although the scenario for a more extended game has been developed. The first four hours will have a low tempo of activity to train the players in the use of the gaming equipment. The play of the second day will constitute the application of the methodology. There will be either three or four players in a game, and all will have had command-related experience in a carrier battle group. The wargame is designed to be played in the Naval Postgraduate School Secure Computing and Simulation Laboratory which is equipped with VAX computers and the necessary display equipment. Further details of the game support software and the physical arrangements in the laboratory are given later.

The Commander's Tactical Decisions

The tactical decisions made by the commander (the players) will determine the favorable or unfavorable conditions of the ensuing offensive and defensive engagements. But the players do not "fight" the detailed engagements. Simulations that incorporate estimated weapon system capabilities make calculations of the engagement outcomes resulting from the players decisions on the disposition of their forces and report the results to the players at the appropriate times. In offensive operations there will be reports of aimpoints destroyed, aircraft lost, targets not found, etc. Enemy and friendly ground truth in the game will be updated automatically (but not reported to the players, unless subject to observation by organic or nonorganic systems). In the case of AAW operations, any damage to the CVBG from air launched missiles will be reported, as well as aircraft lost. If the carrier is damaged, the damage will be reflected in a reduced capability for air operations. If AAW-capable surface ships are damaged, there is a corresponding reduction of the capability in the "inner" air battle (the missile defenses) which is incorporated in the simulation of the AAW results. (Appendix C)

Decisions made by the players influenced by the information in the TRAP broadcast include the following:

*Allocating fighters to defensive AAW operations (vice allocating fighters to support offensive operations) and setting the alert posture of the defending fighters.

*Planning reconnaissance and strike missioons to satisfy the tasking orders.

*Specifying aircraft to be employed in offensive strikes designed either to decrease the perceived threat to the carrier force or to carry out the assigned missions

*Positioning and timing the launch of airborne AAW assets, including the E2Cs and fighters. These decisions will depend on the players' belief as to the direction, weight, and timing of an enemy air attack

The players will be expected to follow current tactical doctrine in the use of their forces. For offensive strikes, this tactical doctrine is incorporated in a Strike Operations Model which directly affects strike planning and the effectiveness of strike execution.(Appendix A) Doctrine for MRAAW near the land in a contingency operation has been undergoing intensive development during the past few years.(Ref. 3) Based on that effort, we are assuming that in a contingency operation the principal threat to the CVBG will be represented by low flying attack aircraft, carrying air-to-surface missiles, supported by escort fighters and stand-off and escort jammers. The players will be briefed on the initial defensive posture at the beginning of the one-half day familiarization session. Subsequent postures and the actions to be taken if an enemy attack is imminent, or in response to enemy jamming, are left to the players and are dependent on any I&W available on the timing and structure of the attacks and feints. The simulations used to determine the outcome of offensive and defensive engagements resulting from the player decisions will be discussed in the following two sections.

An important objective in developing the game has been to provide a game environment that is realistic as far as information flow into the command center is concerned so that the players can feel that they are addressing a military problem. The game will be run in real time so that the dynamic factors will be properly represented. As in the real world, the players will be under time pressures to carry out their assigned missions.

Simulation of Offensive Engagements

The PACFLT THOR simulation (Ref. 4) served as the basis for the Strike Operations Model incorporated into the game. This model is used separately to assist players in strike planning and for determining the results of the execution of a strike. In strike planning, the model in effect substitutes for the normal staff support in sizing the strike force to attack selected targets, recommending aircraft/ordnance combinations for each aimpoint and allocating sorties to the several roles within the strike package.

The effectiveness of each platform or weapon system that plays a role in the strike is specified in a data table. Each target, identified by a P number, is divided into a number of "aimpoints". Each aimpoint is assigned to a vulnerability category depending on its general characteristics, i.e. SAM launcher, ammunition bunker, etc. These vulnerability categories provide the data needed for determination, by the Strike Operations Model, of the weapon loads and number of strike aircraft for offensive actions against the selected targets .

The data table represents the current Navy estimates of system capabilities. Improvements in capabilities would be reflected in changes of the values in the data table. The Strike Operations Model also incorporates the recommended tactics, in accord with Navy doctrine, to be employed by the strike package. Figure 7 shows, using notional entries, the display from which the desired damage to the selected targets can be specified in planning the strike. The "Plan Attack" column controls the player actions. The "Full Target List" window shows the current status of each possible target. Aircraft availability for assignment to a strike and the assignments made are shown in the "Attack Aircraft Allocation" window. Using the players' intelligence picture as it has evolved up to that point, the model also calculates a recommended strike package. The model's recommendations are shown and compared with the players' tentative assignments in "Plan Result Messages" window. The desired aircraft may not be available at that time and the strike may have to be replanned, accepting lower expected damage to the targets, a larger number of less efficient sorties, reduced defense neutralization, or a reduction in the number of targets to be attacked.

While the strike planning is done on the basis of the players' perception of the state of the enemy forces; the execution of the strike by the model is carried out using "ground truth" for the state of the enemy forces and is the basis for determining the aim points destroyed and the strike aircraft losses. Only the aircraft losses are reported to the CVBG commander. As discussed previously, the commander in the game will proceed on the assumption tthat all of the aimpoints attacked are destroyed Offensive actions may be directed at some target that in fact has moved and is not at the expected location. The failure to find the expected target will be part of the strike report results received by the

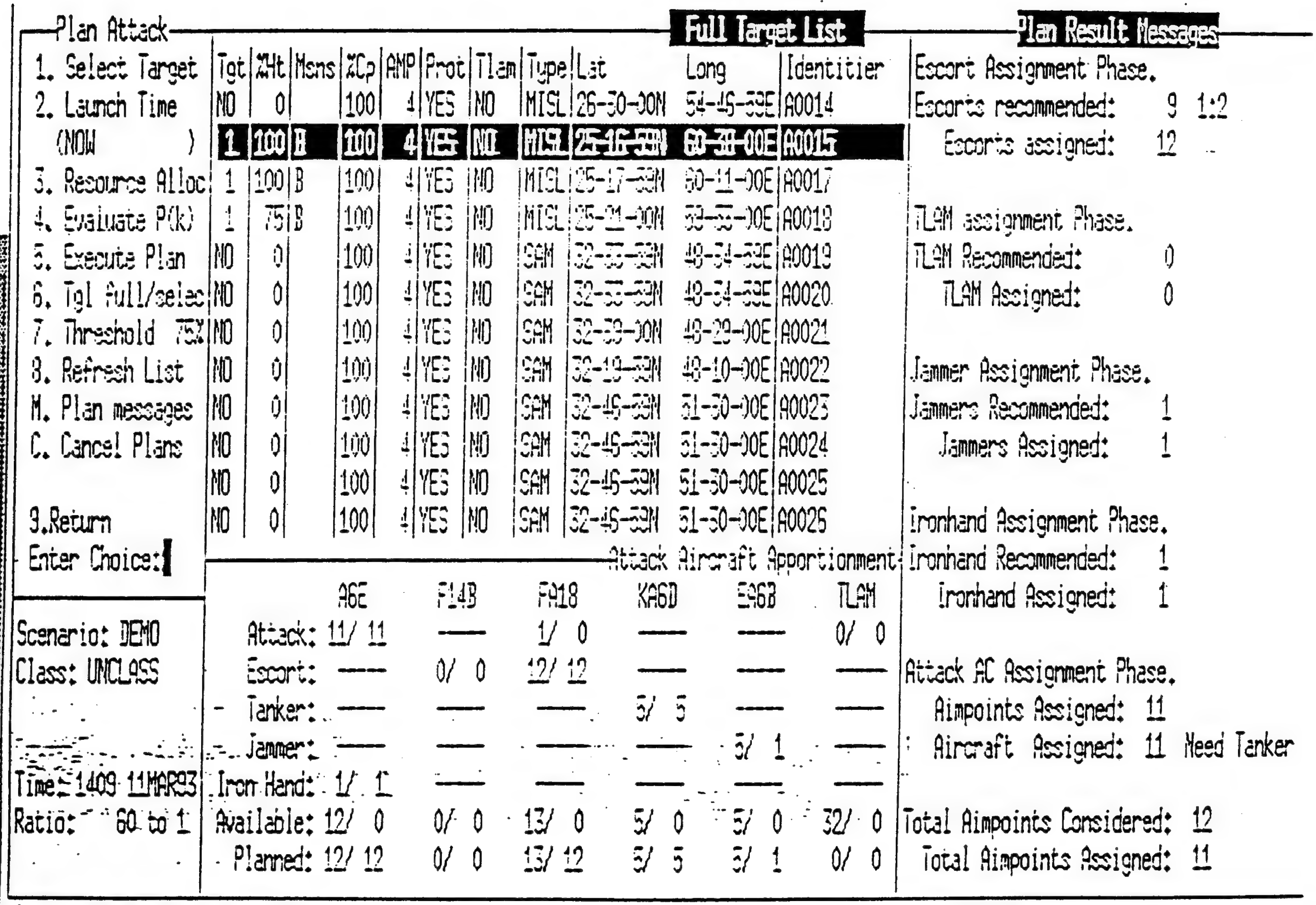

Fig.7. Display for planning strike operations

players. Despite the time delays incurred, the players may decide to send out a reconnaissance mission in a particular area before planning a strike. The reconnaissance report received by the players will be based on "ground truth".

A separate model (Ref. 5) developed by the Center for Naval Analyses is used to determine the availability of CVBG aircraft at any time taking account of expected rates of equipment failure, time for maintenance, aircraft on other missions and aircraft previously lost in prior engagements.

Figure 8 compares the strike results as given by the Strike Operations Model for strike packages based on different player perceptions of the state of enemy air defenses. In this example, the targets are two airfields with four aimpoints each. According to ground truth, the enemy has 9 interceptors in the area that could intercept a raid as well as three operational SAM sites and local AAA. Based on the vulnerability numbers for the selected aim points, the attack objectives can be met by using 8 strike aircraft, one for each aimpoint. Four strike packages have been designed depending on the players' perceptions of the state of the enemy defenses ranging from an accurate view of "ground truth" to the extreme misperception that there are no enemy air defenses to be encountered. The strike planning model called for 11 support aircraft against "ground truth" defenses but none in the extreme case when the players erroneously believed that there were no enemy air defenses. The table shows the resulting wide variation in the number of aimpoints destroyed as well as the penalty in blue aircraft lost for incorrectly characterizing the enemy defenses. The players could have sent support aircraft "as insurance" even if their intelligence indicated an absence of enemy defenses, but that would limit the aircraft available for AAW and so would not be penalty free.

Simulation of Anti-Air Warfare Engagements

Scenario development includes plans for air attacks and feints against the battle group at predetermined times so that with one exception, enemy attacks will not vary from game play to game play. Carrier strikes on enemy airfields can reduce the weight of the planned enemy air attacks. On the basis of aimpoints destroyed according to the execution of the strike simulation, the expected operational capability of the enemy airfields will be reduced. The designation of strikes for the purpose of reducing the air threat to the carrier group is one of the tactical decisions available to the players.

SENSITIVITY TESTING OF GAMING SYSTEM

STRIKE OPERATIONS

Targets: Two airfields with four aimpoints each, plus defenses consisting of nine effective interceptors, three SAM sites and local AAA.

Table of Strike Results
as a Function of Players' Perceptions of Defenses

Eight Strike Aircraft; Support Aircraft Variable, 11 max.

	Strike Results	
Player Perceptions	**Number of Support Aircraft**	**Aimpoints Destroyed**
Full Defenses (i. e. ground truth)	**11**	**6**
Underestimated SAM sites	**8**	**4.5***
No Interceptors, Full SAMs	**6**	**2**
No Defenses	**0**	**0**

* This value is the average of two sub-cases

Fig. 8 Sensitivity of Strike Results to I&W

As noted previously, the principal threat to the CVBG is represented by low flying aircraft carrying air-to-surface missiles. Normally the AAW ships in the CVBG will be deployed between the carrier and the coast. Consequently, the AAW ships are the most exposed to air attack. The first part of the AAW engagement evaluation will be to determine how many of the attack aircraft were intercepted by defensive fighters before they reached missile launch boundaries against the AAW ships. The simulation will then estimate the losses on both sides. Since the available battle space is limited, defensive fighters need to be in the right place at the right time. The two principal methods for acquiring low flying aircraft are represented in the game. If the attack aircraft fly out of the stand-off jamming coverage, the E2C will make the detection and the players can then direct some of the available defensive aircraft for an intercept. Alternatively, defensive aircraft can be sent to search particular sectors at low altitude. Detection and successful engagement is more difficult in this case. Success probabilities obtained in recent fleet exercises will be applied to the game evaluation.

The enemy can send any combination of medium and low altitude aircraft, including escort jammers, escort fighters, and ASM-carrying attack aircraft that he chooses. In general, escorts would tend to be at medium altitude, with the objective of keeping defending aircraft away from the attack aircraft. The script could call for the attack aircraft to penetrate the CVBG defenses in company with the escorts, or relying on deception, to penetrate alone to attempt an undetected approach until they have to pop-up for the required weapons launch maneuvers. Only a few low flying (1000 ft altitude) attacking aircraft will be detected and engaged by CVBG surface ship SAM systems assuming a 35 nmi pop-up stand-off launch range. During the development of the attack, the players will receive reports of escort aircraft at medium altitudes that are detected by surface ships. However, escort jammers accompanying the enemy fighters could limit the ability of the surface ships to determine the course of the raid.

In the scenario situation, a large attack might consist of a total of 16 aircraft: standoff jammers at different azimuths, an escort jammer, eight escorts, and six attack aircraft. The aircraft in such an attack would typically penetrate on one or two axes with the group on one axis possibly being a feint. All aircraft participating in the feint or raid penetrations which survive the CVBG defenses are assumed to return to their staging bases after they reach a pre-specified ASM launch range from the center of the battle group formation.

At least one E2C will be kept airborne at all times while the CVBG is operating in a littoral region under the postulated scenario. Defensive fighters can be positioned in CAP stations at varying strength or in various stages of deck alert. Fig. 9 shows a hypothetical defensive deployment consisting of two CAP stations and an airborne E2C. The locations of the CAP stations are indicated by icons consisting of the capped letter "s". Additionally, the range and bearing of each station from the carrier, and the number of fighters on-station are shown. (In the example, the stations are unoccupied.) The E2C location is indicated by a dot centered in a semi-circle. Around the E2C is diagrammed its nominal detection range against medium-altitude tactical aircraft, with a notch showing the impact of stand-off jamming on the detection capability.

It is anticipated that the attacks against the battle group will begin with stand-off jamming of any E2Cs that are airborne. The players will then follow the recently developed Medium Range AAW (MRAAW) doctrine, taking account of the state of their knowledge of the enemy's attack structure from I&W received via the TRAP broadcast. Actions may include sending fighters along a strobe to obtain a raid count, launching aircraft into a "sponge", or sending aircraft to search for enemy attack aircraft. The MRAAW doctrine is applied by the players in real time as influenced by the state of their I&W, so that their actions immediately impact on the engagement outcome. As described previously , the recommended tactics for offensive operations are incorporated in the Strike Operations Model and I&W influences the results then by its impact on the players' perception of ground truth and, hence, on the selected composition of the strike package.

A key factor influencing the success of the defense will be the ongoing airborne defense posture and the aircraft alert status on the carrier. Aircraft availability may be low because of battle damage or because too many aircraft were sent in support of offensive strikes leaving the resulting airborne and alert posture weak and poorly positioned as a consequence of inadequate I&W. The game-support software tracks the status of each aircraft moving them with realistic delays, through maintenance and the various states of alert in response to player commands and reports the aircraft status in a continuously updated display. Fig. 10 shows the numbers of aircraft in each of the stages of alert as well as the earliest possible launch times for the aircraft in each stage plus other details of the current posture.

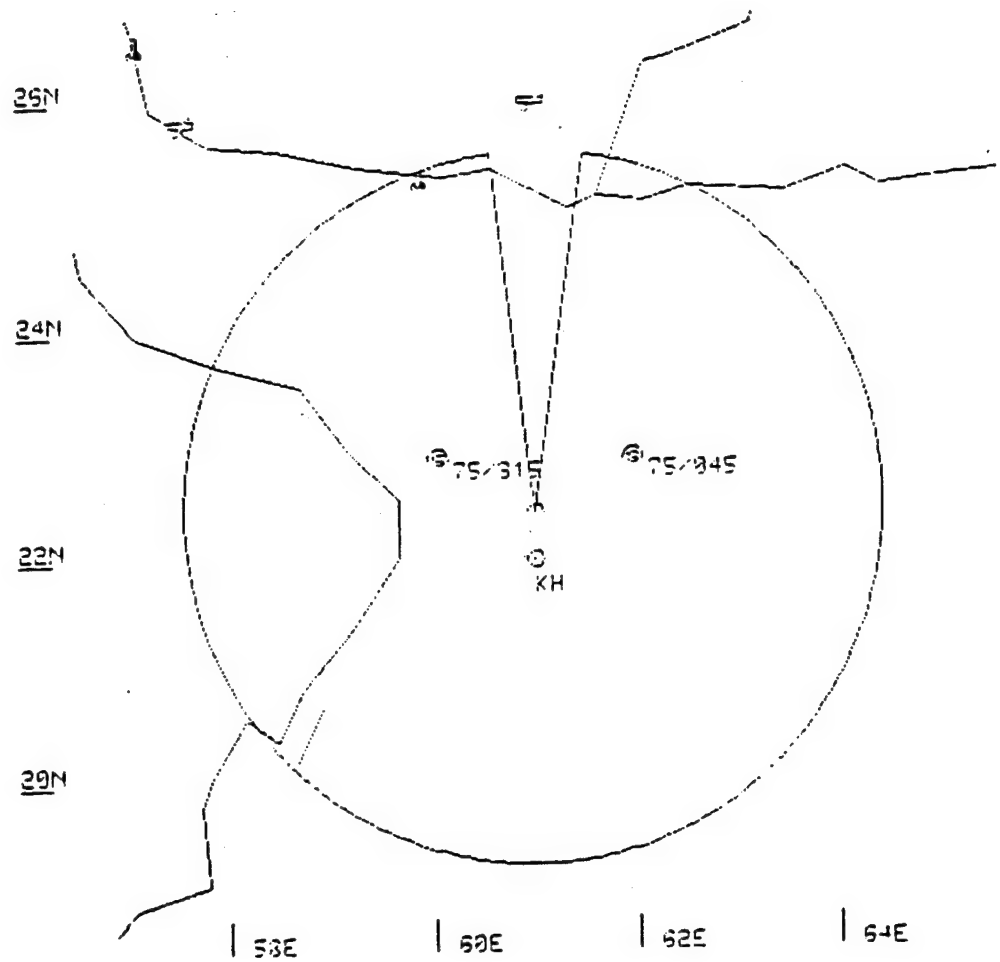

Fig.9. MRAAW defensive deployment

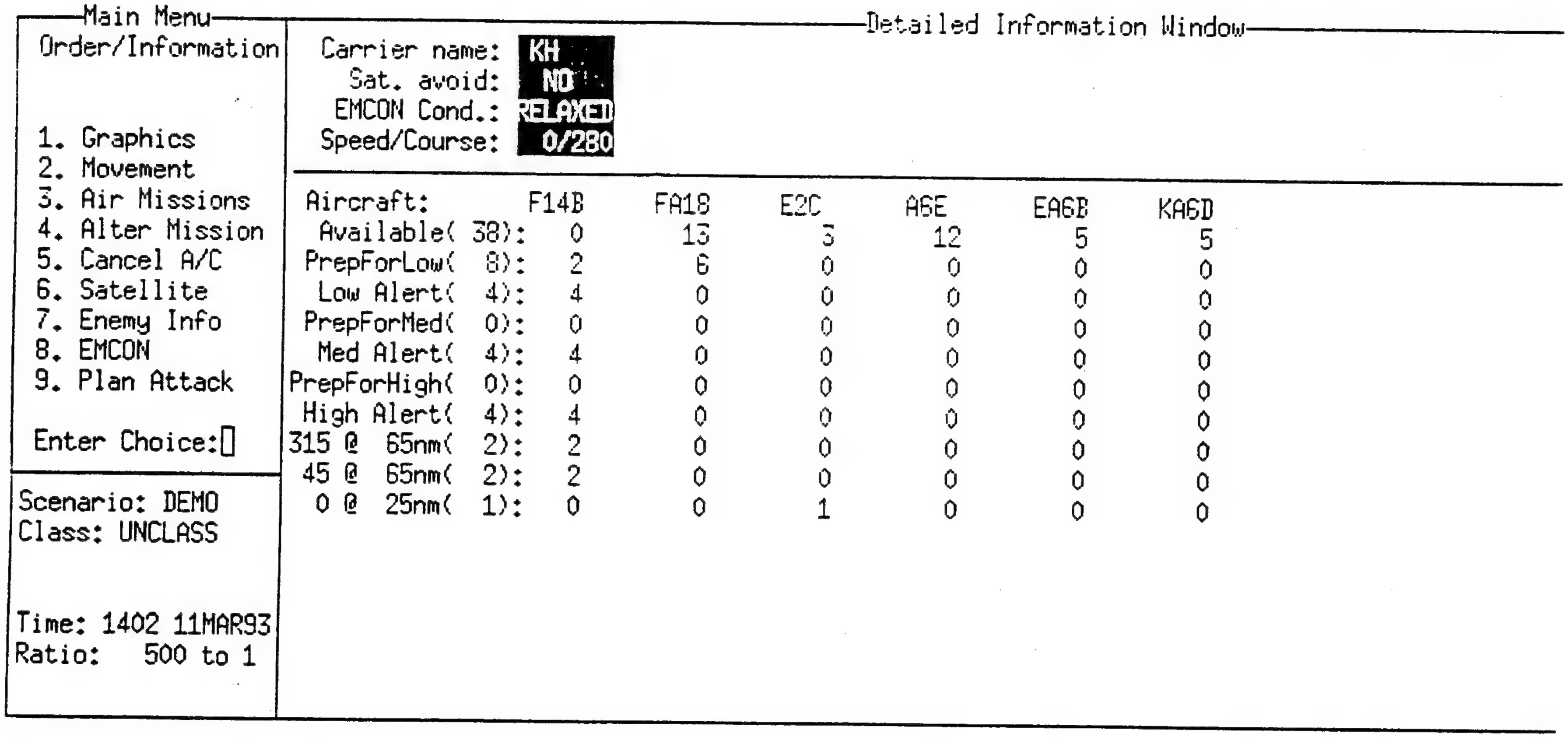

Fig.10 Aircraft alert status display

Figure 11 shows an example of the sensitivity of AAW success to the alert status of the carrier aircraft for an enemy attack coming from an unexpected azimuth at an unexpected time against the CVBG operating 160 nautical miles from shore. In this case, the attack consists of escort fighters and low altitude attack aircraft on two axes 45 degrees apart, supported by escort and stand-off jamming. The failure to predict the direction of the attack leaves some of the airborne CAP in an unfavorable position to counter the attack. Nevertheless, as can be seen from Fig. 11, a robust defense can still be maintained if the alert status allows 8 fighters to be launched from the carrier within 15 minutes of initial detection of the jamming strobes. The procedures used to evaluate of the outcomes of the air battles including possible damage to the surface ships is discussed in Appendices B and C.

Wargame Implementation

The new combat analysis and game support system that has been developed is called GRASS (Gaming Research and Analysis System). In developing GRASS, wherever feasible, segments of existing software packages from other wargames have been adapted. For example, the widely used Navy simulation and game support system known as RESA (Ref. 6)is the underlying source of the timing mechanism, the algorithms for kinetic calculations of platform movements and intercepts, the geographic display drivers and the file structure for keeping the records of game activity. The control of the flow of the background message traffic is accomplished with a modified (and simplified) version of EPISODE, a communications simulation developed for the Federal Emergency Management Agency (FEMA) (Ref. 7). Finally the representation of carrier strike operations is, as noted earlier, supported by a program making extensive use of the design and algorithms of the THOR simulation .

It was necessary to develop many new features for GRASS in order to meet the special requirements of this project. The simulation of the receipt and handling of the TRAP messages (as previously described) required new software. The ability to present a scripted, hence controlled, flow of messages, coupled with the players' ability selectively to accept items of information for incorporation into their intelligence picture is a key to the utility of the game. The splitting of THOR, a closed simulation, into two parts based respectively on ground truth and the players' perception of ground truth has already been discussed. The first portion is used, as in the original version, to evaluate the outcomes of sending variously configured strikes against chosen targets. The new portion is used by the

SENSITIVITY TESTING OF GAMING SYSTEM

DEFENSIVE OPERATIONS

PLAYER PERCEPTIONS	INTERCEPTORS ENGAGED	PENETRATORS KILLED
ATTACK IMMINENT, THREAT AXIS RIGHT	14	ESCORTS – ALL ATTACKERS – 50%
ATTACK NOT LIKELY, THREAT AXIS WRONG	8	ESCORTS – 50% ATTACKERS – 20%

Fig. 11 Sensitivity of AAW Results to Alert Status

players to plan their offensive strikes but is based on the players' Intelligence picture (displayed on the GRASS Graphical Display) derived from the externally generated information flow. As mentioned above, an AAW evaluation model has been developed to determine the engagement outcomes resulting from the player's operational decisions. In developing the model, extensive use has been made of the results of simulations of MRAAW in the Naval Weapons Center WEPTAC simulator (Ref. 8) as well as the results of fleet exercises (Ref. 9). The percentage of ASMs, successfully launched, that hit a ship target and the consequent loss of operational capability resulting from ship damage is based on estimates of the effectiveness of ship point defenses and ship vulnerability (Appendix C).

An important feature of GRASS is the ability to have mobile assets (e.g. SAM and SSM systems, radars, and air defense command centers) as part of the target list. The presence of a target is made known to the players either through TRAP messages or a reconnaissance mission. GRASS generates negative reports when it evaluates strike missions. A negative intelligence report says, "I went to location X expecting to encounter a SAM site, but no detections were made ". This information may then be used to modify the players' intelligence perception but does not alter ground truth.

The wargame is designed to be played in the Secure Computing Simulation Laboratory of the Naval Postgraduate School, which is equipped with VAX computers and the necessary displays and other ancillary equipment. The players will work with four terminals. The GRASS Message terminal is used to receive background messages providing information on developments outside of the CVBG immediate field of interest as well as messages from higher headquarters providing orders and guidance for the players.

The GRASS Graphical display (on both monitors and a large screen)is a color situation display on which organic information (i.e. CAP and E2C stations, detections of enemy aircraft by airborne and surface radars and jamming strobes) is displayed along with the players' intelligence on the locations of potential enemy targets and threats. The players have the ability to remove any undesired information from the display.

The GRASS Order terminal is operated by a computer-support person and is used for executing the players' commands in the game. Orders to change the position of the

CVBG, allocate aircraft between offensive and defensive missions, fly missions, and place aircraft in alert status are all accomplished from this terminal.

Finally a terminal is available to the players for planning strike missions with the Strike Operations Model. An aircraft availability and alert status display is also available at this terminal. In a separate location, ground truth showing enemy targets and aircraft movements together with the position of friendly forces is presented on a graphical display. This makes it possible for observers to keep track of the development of the scenario and the game.

An audio system is used for recording discussions that take place between the players during the game. These discussions provide insights on how the external information was interpreted and to what degree this information affected the operational decisions made during the game. The oral record should be of particular importance where the TRAP message flow reflects the consequences of enemy countermeasures, including interference and deception.

Concluding Remarks

This methodology provides a framework for examining such questions as the required characteristics of new I&W systems, the balance in resources to be allocated to improvements in C4II versus improvements in combat capability,and the potential impact on mission success of enemy actions to degrade the externally provided information. The key to answering these questions is an assessment of the value of information in a tactical scenario. The information flow is the controlled "experimental variable" and the military consequences of the commanders' tactical decisions are directly evaluated by offensive and defensive engagement models.

Externally supplied information may compensate in part for limitations in defensive capability that are inherent in the compressed battle space of contingency scenarios or the information may enhance the ability of the battle group to achieve local air control. With this methodology, the degree to which expanded intelligence on the disposition and movements of enemy air forces have the potential for changing the local military balance can be assessed in the context where the expected combat effectiveness of the CVBG is an integral part of the assessment.

While a wargame by its nature is not a precise quantitative tool, an analysis of the reasons for the observed results can be of great assistance in developing insights and reaching judgments. Since the methodology provides a direct connection between the specific characteristics of the external information being provided and the dynamics and urgency of decision making in a contingency operation, it is a sensitive probe for answering such questions as the following:

a) What frequency of information is needed for offensive as compared to defensive operations?

b) What type of information has the most influence on the decisions and outcomes of the resulting engagements?

c) How much difference does precision of location make?

d) What forms of enemy interference are the most damaging to the usefulness and acceptance by the commanders of the external information? Answers to this question could influence the required "EW hardness" of the collection system design.

One key to answering these questions is the preparation of TRAP messages that accurately represent the specific collection performance of current or proposed systems, or the possible impact on this collection of enemy countermeasures. In the latter case, with a defined "countermeasures scenario" consistent with the enemy's expected level of technical sophistication and resources (developed with the assistance of the intelligence agencies),the appropriate set of TRAP messages can be written and played in the game.

The wargame approach used here for assessing the value of information can be applied to other military "command centers" at higher or lower levels of command, such as joint commands. The essential ingredients are the clear control of information as the experimental variable and credible models for evaluating the military consequence of tactical decisions in real time in a dynamic scenario.

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Appendix A

THE SIMULATION OF STRIKE OPERATIONS

Introduction:

In a war game which is designed to assess the impact of information availability on the mission effectiveness of a carrier battle group (CVBG), it is obviously important to leave all significant decisions in the hands of the players and equally important to simulate with adequate realism, events leading up to and resulting from those decisions. A strike operations model has been developed by Rolands Associates that the players can use to plan strike operations but that can also be used for the evaluation of strike results.

In developing a strike operations model, extensive use has been made of a simulation called "THOR", designed by the Studies, Analyses and Gaming Section of the Plans and Policy Division, Headquarters U. S. Pacific Fleet[1]. The algorithms in THOR embody the tactical doctrine on the employment of CVBG assets which is used in Pacific Fleet studies. The data bases in THOR are structured to allow parameters describing friendly and enemy force capabilities to be easily changed in response to changing scenarios. The THOR algorithms used to assign assets to the missions being simulated and to evaluate the outcomes of strikes, as well as the data base structures, have been retained in the strike operations model incorporated in GRASS.

However, THOR is a closed simulation, which "plans" and executes the next strike on the basis of perfect information on target status and defenses. After a strike, it updates the defense and target data, on the basis of the results of the simulation. of the strike. Since "ground truth" is used in strike planning as well as assessment of results, "THOR" had to be modified so that strike planning by the players would be based on their intelligence picture of enemy targets and defenses rather than ground truth, whereas the assessment of the outcome of the strike would be based on ground truth. In addition, for use in a game covering only one to three days of carrier operations it was both feasible and economical to simplify the treatment of logistical constraints in THOR which was designed for the simulation of more extended air campaigns.

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[1]See the report"THOR 6.0, A STRIKE CAMPAIGN MODEL", November 1991, by Dr. Robert L.Hubbard of the Ketron Division, Bionetics Corporation (now of Rolands Associates Inc.) for the Studies, Analyses and Gaming Section, Plans and Policy Division (Code 64), Commander-in-Chief U. S. Pacific Fleet, Pearl Harbor, Hawaii 96860-7000.

The Data Bases on Targets and Associated Air Defenses:

The scenario determines the target list that will be used in the game. Each target is characterized by a number of aimpoints, with single-sortie kill probabilities listed for a large number of weapon-aircraft combinations applied to each aimpoint. There are also listings of air defense assets that protect the aimpoints, along with parameters that characterize the performance of the defense elements. These data are used in determining the numbers of aircraft, by type and role, in the strike and in assessing the results. In both the original version of THOR and the strike operations model in GRASS, all of the parameters are easy to change to reflect the performance of new or hypothetical systems..

As in THOR, the war game modeling of strike operations requires that all targets that might be selected for strike by the players be listed in the initial data base. This data base is used to assess the results of the strikes ordered in the course of play. However, in the fundamental departure from the THOR design, a totally separate target and defense data base is used by the players to plan the strikes.

At the beginning of play, the second data base would typically contain much of what is in the first but with some omissions and some misinformation. As the game progresses mobile targets (both offensive and defensive systems) will move to new locations. These changes in the situation will be reflected in the assessment data base as they occur. Changes in the planning data base will be made only when the players initiate them based on their interpretation of incoming intelligence from either external sources or organic assets. Post-strike reporting is handled in the same ways.

Computer Support to Strike Planning:

The players may decide to attack targets which are a threat to the CVBG itself and will attack those directed by higher authority within the limits of the battle group's capability. In any case, the computer provides a strike-planning decison aid. When the players indicate an interest in including specific targets in a strike, the computer steps through a sequential process in which it recommends the number of fighter-escorts to be sent to protect the attack aircraft from interceptors, the number of jammers to be sent to reduce the effectiveness of SAM batteries, the number of SAM-suppression (Iron Hand) aircraft to be sent to attack defenses with anti-radiation missiles, and the numbers of attack aircraft to be assigned to each aimpoint in the selected targets to achieve a desired

combined probability of "kill". In the closed simulation of THOR, if there are not enough available sorties of appropriate aircraft types to equal the pre-set minimums (which are based on "ground truth") the proposed strike is dropped. In the game, the players do not have to accept the computer-generated recommendations (which are based on data reflecting the players' interpretation of available information) and can launch the strike with smaller (or larger) numbers of aircraft.

In the game the criteria used in setting the recommended numbers of aircraft for each role include the following:

FIGHTER ESCORTS: The recommended number of fighter escorts is determined by the sum of enemy fighters on bases within a specified region around the intended targets, as shown by the air order of battle maintained by the players; multiplied by a fraction representing the portion that might be available and assigned to the defense and then applying a desired ratio of escort fighters to interceptors.

JAMMERS: The computer counts the number of SAM sites (in the players' perceived intelligence display) that provide coverage of the selected targets, and multiplies the number of sites by a pre-set factor to obtain the recommended number of jammers to be sent.

IRON HAND: A similar procedure is used for determining the desired number of Iron Hand aircraft.

ATTACKERS: A desired probability of aimpoint-kill is established before the game. This is the probability that the delivered ordnance will kill the aimpoint and depends on the weapon, aimpoint hardness and delivery accuracy. In the model, aborts of sorties and attrition en route are accounted for by adding an increment to the desired probability of kill. Given the desired probability of kill for each target, as specified by the players, the computer searches for the available aircraft-weapon combination that reaches that level with the fewest sorties (a given sortie can attack only one aimpoint). The required number of sorties by aircraft type is recommended per aimpoint and the recommendations for all the aimpoints are summed to give the recommendation for the strike. In addition,

each aimpoint suitable for attack by Tomahawk is flagged so players can choose the missile instead of manned aircraft, if the inventory permits.

While the software will not permit the execution of a strike when more than the available number of aircraft of any type are assigned, it will allow strikes with fewer than the recommended numbers of sorties when exigencies require.

Strike Execution:

At the game time at which the strike launch is ordered, after a delay that is a data item, the package is assumed to have assembled in the air. During the launch, aborts are assessed with the rate also being a data item. Further aborts are assessed en route to the target areas. On arrival in the target area, the first action is the air-to-air engagement between defending interceptors and strike-escort fighters. The engagement is broken down into individual "dogfights", the results of which are assessed and then summed to yield the aircraft losses on both sides. Strike aircraft are subject to attrition by interceptors; surface-to-air missiles (SAM), operating in the face of jamming and Iron Hand attacks; followed by anti-aircraft artillery fire.

Dogfights: The results of dogfights are assessed using engagement rules for sequential air-to-air engagements and data parameters assigning relative kill probabilities for these engagements. If there are more interceptors than can be engaged by the escort aircraft, the unengaged interceptors disrupt the strike by attacking randomly chosen jammer, Iron Hand, or attack aircraft.

Thus, the major impact of a serious underestimation of the number of interceptors to be encountered can be felt in two ways: the unengaged interceptors can kill attack aircraft directly or can reduce the jamming and Iron Hand efforts so that SAMs kill more of the attackers.

SAM Engagements: Jammer and Iron Hand aircraft in the strike can operate either alone or in combination to reduce the effectiveness of the SAM defenses according to the following rules:

* All aircraft in the strike fly directly from the carrier to the designated targets. If their route passes through the envelope of a SAM battery, a fixed probability of kill is applied and the survival of each attack aircraft is assessed. A surviving jammer assigned without Iron Hand support to that battery reduces the assigned probability of kill significantly.

* A surviving Iron Hand aircraft without a jammer assigned to the battery is assumed to be seen on the battery's radar and the radar is shut down to avoid attack with anti-radiation missiles. When this occurs, a fixed number of attack aircraft get a "free ride" through the battery's envelope. The number of free rides is a data parameter.

* When, in the preferred tactic, both jammer and Iron Hand aircraft can be assigned to a SAM battery (and survive interceptor attack) the battery's radar is assumed not to see the Iron Hand, which then attacks the battery with anti-radiation missiles. If the battery is assessed as being hit, it is knocked out of the defenses for the duration of the strike (it is fully restored for subsequent strikes) and all attack aircraft move through its envelope unscathed. If the battery is not knocked out, it retains its jammed effectiveness. The considerable synergism between Iron Hand attacks and jamming is reflected in this assessment rule.

* The terminal defenses of anti-aircraft artillery have the last opportunity to engage the attack aircraft before they deliver their weapons on their aimpoints. Those that survive deliver their weapons with a fixed probability of kill. The number of aimpoints assessed as killed are divided by the number of aimpoints in the target; the results are reported as the percent of each target destroyed.

Appendix B

THE EVALUATION OF AAW ENGAGEMENT OUTCOMES

Introduction

In the chosen scenario, the numbers of aircraft in an attack on the CVBG will be relatively small, say six 6 to 16. However, the variation in enemy tactics can be large, including the ratio of missile-carrying fighters to escorts and jammers, the choice of altitudes and axes of penetration and the use of feints. As a result, simulation at the plane-on-plane level becomes a major undertaking. Fortunately, simulations using scenarios very similar to the one used in this game have been carried out to support tactical development and capability assessments (Ref. 3). The prior studies involved similar types and numbers of aircraft, and incorporated current tactical doctrine and weapon effectiveness estimates, as well as intelligence on enemy tactics. We have analysed the reported results to obtain aggregated attrition factors for use in evaluating the effectiveness of the AAW defense for different defense postures both airborne and in deck alert on the carrier. The defense posture maintained by the players will be influenced by the quality and timeliness of the available I&W on the development of a threat to the CVBG. The AAW engagement model then provides comparison of the outcomes resulting from different levels of available I&W. The aggragated attrition factors are handled in the computer as data items and are easily changed to respond to changes in the scenario or to the availability of new information.

Tactical Considerations

In the game, the enemy air attacks on the CVBG are structured to incorporate tactics that are considered feasible for any moderately capable air force. In the initial applications of the methodology, raids and feints are carried out only in the hours of daylight. Attack aircraft with air-to-surface missiles are assumed to fly at low altitude (<1000 ft.). They are supported by medium altitude escort fighters and stand-off and escort jammers. The start of a raid or feint is signalled to the players by stand-off jamming of the E2C radar. Escort fighters and jammers fly a radial course to the carrier. The key point in the evaluation is that, no matter how complex the total attack, it is made up of discrete groups of small numbers of aircraft. There will be groups of escorts at medium altitude and groups of attack aircraft at low altitude. The "group" is the basis for

the evaluation. The effectiveness of the defense will be measured by the fraction of the attack aircraft that succeed in penetrating and launching their missiles.

The players can respond to jamming strobes or aircraft detections by sending interceptors to find and oppose the penetrators. Those sent at medium altitude are assumed to be preoccupied by the enemy fighters and do not interact with any low-altitude attack aircraft. Those interceptors sent at low altitude are assumed to engage any penetrating attack aircraft, with one exception. If there are accompanying medium-altitude, escort fighters covering the attack aircraft and no interceptors are assigned to engage them at medium altitude, the low-altitude interceptors are assumed to be engaged by the escort fighters and judged as unable to reach the attack aircraft.

The enemy aircraft that survive the interceptor engagements penetrate to an assumed ASM launch line around the CVBG location where they launch their weapons and turn back.

The Evaluation Algorithms

Each of the groups of penetrating aircraft, following its scripted track, is maintained by the computer as a separate "ground truth" entity. As interceptors are assigned by the players to investigate jamming strobes or to intercept detected tracks, they are paired with the particular group of hostile aircraft that they engage. Each pairing is checked to see that the intercept can be completed prior to the group reaching the ASM launch line. If it can, it is added to a total of "engaging interceptors" for that group. As each group reaches the ASM launch line, the final number of "engaging interceptors" is read by the computer and multiplied by an "attrition factor", i. e. "kills per engaging interceptor". This is an estimate of the number of hostile aircraft in that group that are "killed". The attrition of the interceptors is also estimated.

When the intercepted group consists of low flying attack aircraft, the number of them evaluated by the algorithm as surviving is multiplied by the assumed ASM-load-per-aircraft to determine the number of ASMs successfully launched against the CVBG. Some leakage rate through the point defenses of the ships is then estimated to arrive at the number of missiles causing damage to the CVBG. The representation of this damage and the effect of this damage on the strike and defense capability of the CVBG are discussed in Appendix C.

Appendix C

ASSESSMENT OF DAMAGE TO SURFACE UNITS OF THE CVBG

Introduction

The damage resulting from the ASMs which penetrate the ship point defenses is assessed in two steps. The first step is to divide the missile "hits" among the battle group's surface units. The second step is to assess an operational degradation resulting from each hit. All of the assessment parameters to be discussed are drawn from Navy sources and are handled as data items which are easily changed to adapt to differing scenarios and ship vulnerability estimates.

The Assessment of Damage to AAW-capable Escort Ships

Because of their greater numbers, forward deployment and defensive functions, the AAW-capable surface escorts are deemed to receive more than one-half the hits. Each successive hit on a given escort vessel produces an increasing percentage reduction in residual air defense capability. The overall AAW impact of a given raid on the CVBG is evaluated in the following steps:

1. The number of ASMs surviving to impact is multiplied by the assumed fraction directed to AAW ships to obtain the number of .hits on AAW vessels.

2. Each hit is allocated to individual escorts in turn, until each has received one hit and the allocation of second hits begins.

3. The loss in point defense capability for each ship is estimated based on the number of hits received.

4. The initial contribution of each escort is reduced in step 3. and the reduced contributions are summed to give the new, lower overall percentage of kill of incoming missiles.

Assessment of Damage to the Carrier

The fraction of ASMs surviving-to-impact that are assigned to the carrier currently reduce the residual aircraft inventory on the carrier by a percentage that increases with each succeeding hit. Each aircraft type is reduced in the same proportion. This algorithm, however, is in the process of modification to also reduce the aircraft launching rate of the carrier, in addition to the numbers of aircraft available for launch.

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